

HOW DRUNK ARE U.S. DRIVERS? MEASURING THE EXTENT, RISKS AND COSTS OF DRUNK DRIVING

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ABSTRACT

This study develops and applies an algorithm with broad applicability for estimating vehicle miles traveled by Blood Alcohol Level (BAL) from police accident report data. In the United States, an estimated one in 120 miles was driven drunk in 1992-1993. For 1 in 7 miles driven after 1 AM on weekend evenings, a drunk sat behind the wheel. The estimated cost per DWI vehicle mile was \$5.80 compared to \$0.11 per sober mile. Males, those age 21 to 29, and those driving between 10 PM and 4 AM had the greatest percentage of alcohol-impaired driving. These estimates are computed, in part, from early-1960s data on crash odds by driver BAL and assume crash odds by BAL relative to sober do not vary with driver age and sex. The method reproduces alcohol-positive miles from roadside surveys at night well, but seems to over-estimate high-BAL miles. Direct field validation is highly desirable.

Information on the amount of driving while intoxicated (DWI) or under the influence of alcohol is important in developing traffic safety policy. While estimates of alcohol-related injuries, lives lost, and costs provide measures of outcomes associated with alcohol consumption, the amount of driving at various blood alcohol levels (BALs) provides a more direct measure of the magnitude of the underlying problem. Answers to the questions of who is involved (e.g., age groups, gender, etc) in alcohol-involved driving and when this driving occurs are useful for developing educational programs and targeting traffic safety enforcement. Measures of BAL exposure can be used to estimate the likelihood of an alcohol-

related crash or arrest. They can provide direct evidence of the efficacy of traffic enforcement policy aimed at apprehending drunk drivers. In developing cost benefit analyses of specific policies, reductions in the amount of DWI can be directly translated into the cost savings per mile driven. While estimates of health effects and costs are in the literature (Rice et al., 1990; Miller and Blincoe, 1994; Miller et al., 1998), estimates of the amount of drunk driving are available only for evening hours (Wolfe, 1986).

In this paper, we present measures of driving exposure based on BAL. Since such data are not directly available, we develop an algorithm for estimating vehicle miles traveled at various BALs. The algorithm applies data on crash odds ratios by driver BAL and the number of crashes at different BALs. It is straightforward and can be applied to individual states or communities and to other countries.

From the estimates of BAL exposure, we estimate other measures which are directly relevant to traffic enforcement policy aimed at DWIs, such as the percentage of miles driven by BAL at different times of the day and by weekday versus weekend (6 PM Friday to 1 AM Monday), the trend in driver sobriety between 1984 and 1993, differences in drunk driver demographics, and the probability of a crash or arrest per DWI trip. Combining the exposure measures with cost and other data, we estimate costs of alcohol-involved driving per vehicle mile traveled and per trip by BAL. These estimates provide answers to such questions as: Has drunk driving declined with increased public awareness and interventions over the past 10 years? Who is driving under the influence of alcohol? When are the greatest proportion of drivers under the influence? How likely is a drunk driver to be involved in a crash? How likely is a drunk driver to be arrested for driving under the influence? How do the costs of drunk driving compare with the costs of sober driving, per mile driven or per trip?

METHODS

All our exposure measures hinge on knowing vehicle miles traveled at various levels of intoxication. We distinguish four groups: sober, alcohol on board but BAL less than 0.08%, BAL over 0.08% but less than 0.10%, and BAL at least 0.10%. Increasingly, states are moving from a 0.10% legal limit for intoxication to a 0.08% level.

We employed four different data sets to obtain information on alcohol-involved drivers. The National Highway Traffic Safety Administration's (NHTSA's) 1991-1993 General Estimates System (GES; NHTSA, 1994) provides a relatively recent sample of the number of vehicles involved in police-reported crashes, whether the police reported alcohol involvement by the driver, and whether the police reported an injury in the crash. GES does not provide the BAL of the drinking driver. The BAL distribution in alcohol-involved crashes came from NHTSA's 1984-1986 National Accident Sampling System (NASS; NHTSA, 1987) and 1988-1991 Crashworthiness Data System (CDS; NHTSA, 1995). CDS contains only data on passenger vehicle towaway crashes; 1984-1986 NASS data (the most recent for non-CDS crashes) provided blood alcohol levels for alcohol-involved drivers in other types

of crashes. We also used NASS data to determine drivers' BALs in 1984 to 1986.

In approximately 40% of alcohol-involved crashes, driver BAL is unknown, since some states do not routinely collect such information. If the police report cited the driver as drunk but did not provide a BAL test result, we assume that the driver is at BAL greater than 0.10%. In sensitivity analysis, unknown cases are allocated to both the 0.08% to 0.099% and greater than 0.10% BAL groups.

After applying the NASS and CDS distribution of BAL in alcohol-involved vehicles to the GES alcohol-involved vehicles, the GES data were adjusted to account for police under-identification of driver alcohol involvement in crashes (Blincoe, 1996; Blincoe and Faigin, 1992). Studies by Terhune (1982), Dischinger and Cowley (1989), Soderstrom et al. (1990,1991), and Maull et al. (1984) compare police and hospital BAL data. From these studies Miller and Blincoe (1994) develop a method to adjust police data for the under-identification of driver alcohol involvement. By this method counts of BAL positive vehicles with no injury and $BAL < 0.10\%$ vehicles in which there was an injury are adjusted 272% upwards. All $BAL \geq 0.10$ vehicles with injury are adjusted 83% upwards. The methods are described further in Miller and Blincoe (1994).

Our method for computing driver sobriety relies on solving five simple equations in five unknowns. Four of these equations state that the fraction of crash-involved vehicles with a given driver BAL equals the fraction of miles driven at that BAL times the odds of a crash at that BAL relative to sober. Crash odds ratios are obtained from the landmark study by Borkenstein (1974), which measured BALs of control drivers (matched by crash site and time period). The fifth equation simply states that the fractions of miles driven at different BALs sum to 1. To have only five unknowns in these equations, we use odds of crashing at different positive BALs versus sober. The Appendix derives and solves the system of equations, and provides an example of their application.

We applied these same equations to crash vehicle counts by time of day and weekend or weekday, by driver sex, by driver age, and from different time periods. These equations can readily be used with national, state, or local counts of crash-involved vehicles by driver BAL from police crash report systems.

RESULTS

Table 1 presents estimated millions of vehicle miles traveled by BAL for the years 1984-1986, 1991 and 1992-1993. In 1992-1993, an estimated 1.2% of miles were driven with a BAL greater than zero; 0.7% of miles were driven at BAL greater than 0.10%. Table 1 also indicates that drivers are increasingly sober. In 1984-1986, an estimated 2.25% of all miles were driven with alcohol on board. By 1991 that figure dropped to an estimated 1.5% and by 1992-1993 to 1.2%. Estimated miles driven at BALs at or above 0.10% dropped from 1.4% in 1984-1986 to 0.85% in 1991 to 0.7% in 1992-1993.

Table 1--Millions of Vehicle Miles Traveled by BAL and Time Period

Blood Alcohol Level	1984-1986 <u>Miles (%)</u>	1991 <u>Miles (%)</u>	1992-1993 <u>Miles (%)</u>
BAL \geq .1%	24,800 (1.4%)	18,500 (0.85%)	16,000 (0.71%)
0.08% \leq BAL<.1%	2,400 (0.14%)	2,300 (0.11%)	1,900 (0.08%)
0%<BAL<.08%	12,600 (0.71%)	10,100 (0.46%)	8,200 (0.36%)
BAL=0%	1,734,000 (97.76%)	2,141,000 (98.58%)	2,270,000 (98.84%)

Table 2--Percent of Total Miles Driven, by Method of Allocating Drivers Ticketed for DWI but with Unknown BAL, United States, 1991

Blood Alcohol Level	% of Miles with Unknown BAL Allocated Between 0.08%-0.099% and BAL>0.10%	% of Miles with Unknown BAL Allocated to BAL>0.10%
BAL \geq .1%	0.85%	0.83%
0.08% \leq BAL<.1%	0.11%	0.29%
0%<BAL<.08%	0.46%	0.46%
BAL=0%	98.58%	98.42%

Table 3 - Cost per Mile Traveled, by Blood Alcohol Level and Cost Category, United States, 1992-1993 (in 9/95 dollars)

	<u>Medical</u>	<u>Monetary</u>	<u>Comprehensive</u>
BAL \geq 0.10%	\$0.31	\$2.37	\$5.82
0.08% \leq BAL<0.10%	\$0.07	\$0.99	\$2.53
BAL=0%	\$0.01	\$0.05	\$0.11

Table 2 presents estimated vehicle miles traveled in 1991 if drivers with BAL unknown but elevated instead are allocated into the BAL categories above 0.08% in proportion to drivers with known elevated BALs. Under either allocation, about 0.8% of miles driven are with BAL greater than 0.10% and about 0.7% of miles driven are between 0.01 and 0.08% BAL. The 0.08% to 0.10% BAL mileage estimate is more sensitive to the allocation of alcohol-involved cases of unknown driver BAL, varying from 0.1% to 0.3%.

Miles driven drunk by those under the age of 21 fell by a particularly large amount in recent years. In 1984-1986 drivers under and over age 21 had similar profiles of alcohol-involved driving. Those under 21 had alcohol on board during an estimated 2.25% of their miles and BALs exceeding 0.10% on 1.2% of their miles. By 1992-1993, these figures plummeted to around 0.7% and 0.4%. The percentage of alcohol-involved miles was 35% lower than it would have been if drinking and driving had declined at the same rate that it did for drivers over age 21.

The percentage of miles driven at BAL of 0.08% and over varies substantially by driver age (figure 1). Compared to other age groups, drivers under 21 drive the second-lowest proportion of miles drunk, an estimated 0.45%, behind those over 55 years of age, at 0.25%. Drivers age 21 to 29 drive the greatest proportion of their miles drunk. Drinking and driving patterns also differ markedly by gender. Men are four times as likely as women to drive after drinking (1.6% of miles versus 0.4%).

Policies such as sobriety checkpoints rightly are targeted to particular times of day and days of the week. As figure 2 shows, proportionately more miles are driven drunk on weekends (2.2%) than on weekdays (0.6%). The proportions also vary greatly by time of day: from an estimated 0.1% weekdays between 9AM and 1PM to 14.9% on weekends between 1AM and 6AM. That poses serious crash risks to shift workers who often must drive home late at night. Every weekday night, from 10PM to 1AM, one in 13 drivers is drunk ($BAL \geq 0.08\%$). Between 1AM and 6AM on Saturday and Sunday mornings, 1 in 4 drivers has alcohol on board and 1 in 7 drivers is drunk.

The number of DWI trips per DWI crash measures the riskiness of drunk driving. The National Personal Transportation Survey (1995) provides average trip length by type of trip. Since we expect that most trips taken by those under the influence are of a social nature (Damkot, 1979; Foss, 1990; Palmer, 1986), we employ a weighted average of visits to friends and relatives and other social and recreational trips. The average trip equals 9.7 miles. To measure the number of crashes, we used 2,993,000 DWI crash vehicles (10.5% of all crashed vehicles), computed from 1992-1993 GES data. Dividing VMT at $BAL \geq 0.10\%$ by (9.7 multiplied by the number of DWI crash vehicles) suggests that roughly 1 in 625 DWI trips resulted in a crash in 1993. This implies that the probability that a DWI trip will result in a crash is $1/625$, or 0.0016. By comparison, the probability that a non-DWI trip will result in a crash is $1/9210$, or 0.0001. With our method, the ratio of these estimates is the Borkenstein odds ratio.

Figure 1. Percent of Miles Driven Drunk (BAC \geq .08) by Driver Age, United States, 1992-1993

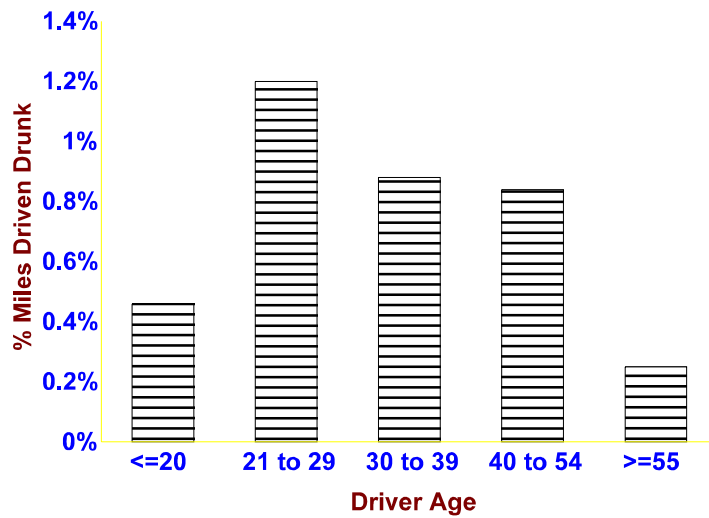
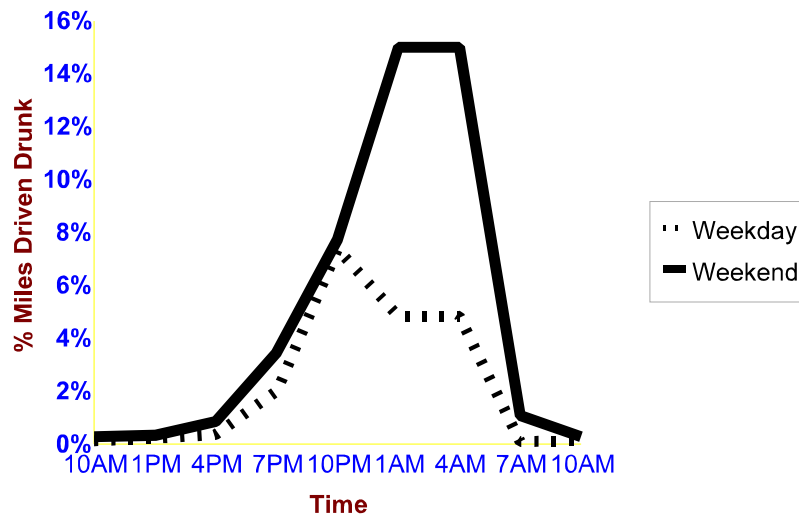


Figure 2. Miles Driven Drunk (BAC \geq .08) by Time of Day and Day of Week, United States, 1991



A useful indicator for evaluating traffic enforcement policy is the arrest rate. From Uniform Crime Report (1994) data on the number of DWI-related arrests (or estimated arrests for non-reporting jurisdictions), we calculate the arrest rate as the number of arrests per year divided by the number of DWI trips. An estimated 1 in 1225 DWI trips results in an arrest. The probability that a DWI trip will result in an arrest equals 0.0008 (1/1225). Subtracting the GES estimate of annual DWI crash arrests in 1992-1993 from total arrests, we also calculated DWI non-crash trips that result in an arrest. The probability that a DWI non-crash trip results in an arrest is about 1 in 1700 or 0.0006. Thus, the likelihood that a drunk driver will get into a crash is 0.0016, twice the probability of an arrest (0.0008) and 2.5 times as likely as an arrest in the absence of a crash (0.0006). The fraction of DWI trips that result in crash or arrest is $1 - (1/\text{DWI non-crash trips that result in arrest}) - (1/\text{DWI trips that result in crash})$. We estimate that about 1 in 450 trips results in a crash or an arrest; a probability of 0.0022.

Combining the VMT data with published crash cost data (Miller, Lestina, and Spicer, 1998), we calculate crash costs per vehicle mile traveled by BAL. Costs include those for medical care, public programs (police, fire, emergency medical, and emergency transport), property damage, future earnings and lost quality of life. The average mile driven at or above 0.10% in 1993 had estimated safety costs of \$5.80 (in 1995 dollars). Cost per mile at 0.08%-0.099% was \$2.50. Cost per mile at 0.08% and above was \$4.90 to \$5.40. By comparison the average mile driven sober cost about \$0.11 (excluding costs in crashes with alcohol-involved drivers). Thus, depending on the BAL cutoff for DWI, the excess cost per DWI mile is between \$4.80 and \$5.70.

Table 3 breaks the costs down by cost category. Cost per mile for the 0.01%-0.079% BAL category was not tabulated because police test and code alcohol levels in serious crashes more often than in minor-injury and property-damage-only crashes in the lower portion of this BAL range. Thus, cost estimates for this range, which are derived from crashes where drivers were tested, probably are exaggerated.

Safety costs to people other than the drinking drivers - external costs - are often viewed as relevant when analyzing whether the public should intervene in drunk driving. We calculated the external costs using the methods of Levy and Miller (1995) with data from Miller et al. (1998). External costs exclude costs paid by the drunk driver. The external cost per mile driven above 0.10% averaged about \$3.15, compared to \$1.85 at BALs of 0.08%-0.099%, and \$0.05 per mile driven sober. Again, the differences are substantial. Note that these are total costs per mile driven, including costs of crashes that would have occurred if all drivers were sober.

Another useful indication of the costs of alcohol abuse is provided by the costs per trip. Multiplying the average trip length by the DWI cost per VMT, the average cost per DWI trip is \$53.90, compared to \$1.00 per non-DWI trip. The drunk driver's cost (internal cost) is \$28.80 per trip $((\$3.05/\$5.70)*\$53.90)$. The community's cost (external cost) is \$25.10. A cab ride home, at drinker or community expense, seems cheap by comparison.

DISCUSSION

The estimates of miles driven at various BALs relies on Borkenstein et al.'s (1974) study of drivers in police-reported crashes in Grand Rapids, MI in the early 1960s. That study employed a case-control method; crashes per driver at a particular BAL were compared to crashes per driver at zero BAL. Although the study is old, other recent studies (Levy and Miller, 1995; Hurst et al., 1994; Evans, 1990) rely on its classic data. Other studies using a similar methodology to Borkenstein (Perrine et al., 1971; Farris et al., 1977) obtain roughly consistent estimates with smaller and less representative samples. For more recent years, Perneger and Smith (1991) and Zador (1991) use different methodologies to obtain odds ratios. Perneger and Smith obtain similar results to Borkenstein using police reports of crash cause. Zador obtains slightly higher odds ratios for fatal single vehicle crashes.

The Borkenstein data were analyzed tabularly without the benefit of multivariate regression. This limitation gave rise to the "Grand Rapids dip", an anomalous finding that drivers at very low positive BALs had lower crash odds than sober drivers. Several analyses, notably Hurst (1973) and Hurst et al. (1994), have shown that the Grand Rapids dip is spurious. It results from differences in the demographics of sober drivers and ones at very low positive BALs in the data, not from a risk-reducing effect of alcohol.

The Hurst studies underline an important caveat about our estimates by age group, sex, time of day, and time of year. The estimates assume that odds of crash by BAL does not vary with these parameters (for example, that the odds of a crash at 0.10% relative to sober does not vary with driver age). Odds ratios probably vary some. Thus, the uncertainty around these sub-estimates is larger than around our main estimate of miles driven by BAL. An ongoing NHTSA study should yield odds ratios for subgroups, as well as updating the Borkenstein data. That information is badly needed, especially for younger drivers who are less experienced with drinking and driving.

Table 4 shows our estimates of the presence of positive driver alcohol levels are similar to estimates from roadside surveys (Wolfe, 1986; Voas, 1990; Voas et al., 1996, 1997). However, this does not mean that the percent distribution by BAL matches well. With limited studies where we were able to make more detailed comparisons by BAL, it appeared the Borkenstein odds ratios may be too low at high BALs. If they are, the percent of miles driven drunk would be lower, the cost per mile driven drunk would be higher, and the percent of alcohol-involved costs attributable to alcohol would be higher. Specifically with the BAL profile of the 1997 National Roadside Survey (Voas et al., 1998) and the 1992-1993 crash profile used in our methods (obviously not an exact match), the odds ratios would be 49 to 61 above 0.10% BAL (similar to the odds ratios for fatal crashes in Perneger and Smith and three times Borkenstein's all-crash ratios), 2.6-4.2 at 0.08%-0.099% (compared to Borkenstein's 2.7), and 0.7-1.3 at lower BALs (compared to Borkenstein's 1.1).

Another limitation is that the analysis does not distinguish whether DWIs are the cause of a crash. From the Borkenstein study,

Table 4 - Comparison of Estimated Percentage of Miles Driven BAL-Positive on Friday and Saturday Nights from the Current Study with the Measured Percentage of Drivers BAL positive from Roadside Surveys

	<u>Time</u>	BAL Positive <u>≥0.0%</u>
National Roadside Survey, 1986 (Wolfe, 1986)	10PM-12AM	14.8%
	1AM-3AM	24.6%
National Roadside Survey, 1996 (Voas, 1997)	10PM-12AM	14.2%
	1AM-3AM	26.3%
Minnesota, 1990 (Voas, 1990)	night	27.1%
California, 1996 (Voas, 1996)	9PM-2AM	17.9%
Current Study	10PM-1AM	14.9%
	1AM-6AM	22.4%

Miller and Blincoe (1994), Levy and Miller (1995), and Evans (1990) estimate that about 90 percent of crashes involving a DWI driver are caused by the DWI driver. Based on these results, about 90% of the costs in crashes at BALs of 0.08% and over can be attributed to alcohol.

CONCLUSIONS

An estimated one in 120 miles was driven drunk in 1993. Miles driven drunk fell substantially between 1985 and 1993, especially for those under the age of 21. This age group now has the lowest percentage of miles driven drunk of any under age 55.

Factors that may explain the decline in youth drunk driving include the nationwide increase in legal minimum drinking age to 21 and 10 states passing laws between 1987 and 1991 establishing low limits for alcohol use by youthful drivers (Hingson et al., 1995). While others (Wagenaar, 1986) find a decline in the number of alcohol-related crashes involving youth, we find the more direct relationship that miles driven by youth fell during the period when youth drinking and driving policies were implemented.

We also found that a drunk driving trip rarely has adverse results. Only an estimated 1 in 625 DWI trips results in a crash and 1 in 1700 DWI trips without a crash results in an arrest. Such data can be used to evaluate traffic enforcement activity. The data also suggest that there is potential to improve the current situation. In particular, males, those age 21 to 29, and those driving between 10 PM and 4 AM (particularly on weekends) are target groups for reducing drinking and driving.

Finally, we estimate that the cost per DWI mile is \$5.80 compared to \$2.50 per mile at BALs of 0.08%-0.099% and \$0.11 per non-DWI mile. These estimates imply that those driving at BALs of 0.08% and above are 25 to 50 times as costly to have on the road as

sober drivers. The external costs of DWI driving translate to about \$25 per trip, far more than a community-paid cab ride home. These results are useful in conducting cost-benefit analyses, and have striking implications for public policy. They also suggest major costs to businesses when their drivers are under the influence. By preventing driving after the multi-drink business lunch, a firm can expect to save \$55 per trip either directly or through decreased insurance costs.

APPENDIX

To denote the fraction of vehicle miles traveled at various BAL levels, we use the following notation:

VMT_{10} = Fraction of Vehicle Miles Traveled at $BAL \geq 0.10\%$

VMT_8 = Fraction of Vehicle Miles Traveled at $0.08\% < BAL < 0.10\%$

VMT_1 = Fraction of Vehicle Miles Traveled at $0\% < BAL < 0.08\%$

VMT_0 = Fraction of Vehicle Miles Traveled at $BAL = 0\%$.

To denote the fraction of vehicles involved in crashes we used the following notation:

V_{10} = Fraction of vehicles involved in crash where $BAL \geq 0.10\%$

V_8 = Fraction of vehicles involved in crash where $0.08\% < BAL < 0.10\%$

V_1 = Fraction of vehicles involved in crash where $0\% < BAL < 0.08\%$

V_0 = Fraction of vehicles involved in crash where $BAL = 0\%$

It is essential that V_{10} and V_8 be adjusted upwards for police under-identification of alcohol involvement in injury crashes, with an offsetting reduction in V_0 .

We computed crash odds by driver BAL relative to sober from data in Borkenstein et al. (1974). Following Evans (1990), we computed odds ratios by dividing the ratio of those with $BALs \geq 0.10\%$ in crashes relative to their presence among sampled drivers by the ratio of those with zero $BALs$ in crashes relative to their presence among sampled drivers. Denoting the odds of a crash at $BAL \geq 0.10\%$ by R_{10} , and similarly for the odds of a crash at other $BALs$, the odds ratio at a $BAL \geq 0.10\%$ is $R_{10}/R_0 = 16.014$ and the odds ratio between 0.08% and 0.10% is $R_8/R_0 = 2.736$. Because most of the drivers identified with a positive BAL below 0.08% are likely in the upper range, we used the odds ratio of drivers with $BALs$ between 0.03 and 0.079 , $R_1/R_0 = 1.147$. Stated differently,

$$R_{10} = 16.04 * R_0$$

$$R_8 = 2.736 * R_0$$

$$R_1 = 1.147 * R_0$$

Thus, per vehicle mile traveled, a driver with a BAL of 0.10% or above is on average 16 times as likely to cause a crash as a sober driver.

To derive the fraction of vehicle miles traveled at $BAL \geq 0.10\%$, we use the equation:

$$V_{10} = R_{10} * VMT_{10}$$

or the fraction of vehicles in crashes equals the odds ratio per mile driven multiplied by the fraction of miles driven at this BAL .

Substituting $(16.04 * R_0)$ for R_{10} , we can solve for VMT_{10} as:

$$VMT_{10} = V_{10} / (16.04 * R_0) \quad (1a)$$

Similarly, equations can be obtained for other VMTs.

$$VMT_8 = V_8 / (2.736 * R_0) \quad (1b)$$

$$VMT_1 = V_1 / (1.147 * R_0) \quad (1c)$$

$$VMT_0 = V_0 / R_0 \quad (1d)$$

These estimates of the fraction of miles driven by BAL must sum to 1.

$$VMT_0 + VMT_1 + VMT_8 + VMT_{10} = 1 \quad (1e)$$

Therefore, we have five equations (1a-1e) and five unknowns (VMT_0 , VMT_1 , VMT_8 , VMT_{10} , and R_0). We solve for the five unknowns by replacing the fraction of vehicles in crashes by BAL (V_0 , V_1 , V_8 , V_{10}) with the values determined from the crash data, then substituting equations (1a) through (1d) into equation (1e) to solve for R_0 . Solutions for VMT_0 , VMT_1 , VMT_8 , and VMT_{10} are derived by directly substituting vehicle miles and R_0 into equations (1a) through (1d).

For example: The local police jurisdiction reports the following driver/vehicle involvement in crashes:

	No Injury	Injury	All
Driver BAL=0%, or no alcohol involvement reported	15,000	5,000	20,000
Driver $0\% < BAL \leq 0.079\%$	300	200	500
Driver $0.08\% \leq BAL \leq 0.099\%$	100	150	250
Driver $BAL \geq 0.10\%$	400	600	1,000
Alcohol involvement reported, BAL unknown	200	300	500
All drivers	16,000	6,250	22,250

Start by allocating the Alcohol-involved/BAL-unknown cases to $BAL \geq .10\%$ (or allocate proportionately between $BAL \geq .10\%$ and $0.08\% \leq BAL \leq 0.099\%$):

	No Injury	Injury	All
Driver BAL=0%, or no alcohol involvement reported	15,000	5,000	20,000
Driver $0\% < BAL \leq 0.079\%$	300	200	500
Driver $0.08\% \leq BAL \leq 0.099\%$	100	150	250
Driver $BAL \geq 0.10\%$	600	900	1,500
All drivers	16,000	6,250	22,250

Next, use the method in Miller and Blincoc (1994) and Blincoc (1996) to adjust the crashed vehicle counts for police under-identification of driver alcohol-involvement in crashes. For BAL positive/no injury and $BAL < 0.10\%$ /injury vehicles, divide counts by 0.269. For $BAL \geq 0.10\%$ /injury, divide counts by 0.546.

	No Injury	Injury
Driver BAL=0%	(16000-3717)=12,283	(6250-2949)=3,301
Driver $0\% < BAL \leq 0.079\%$	(300/.269)=1,115	(200/.269)=743
Driver $0.08\% \leq BAL \leq 0.099\%$	(100/.269)=372	(150/.269)=558
Driver $BAL \geq 0.10\%$	(600/.269)=2,230	(900/.546)=1,648
All Alcohol-Involved	3,717	2,949
All drivers	16,000	6,250

Now convert the crashed vehicle by BAL counts to fractions.

Driver BAL=0%	15,584/22,500 =.7004 = V_0
Driver $0\% < \text{BAL} \leq 0.079\%$	1,858/22,500 =.0835 = V_1
Driver $0.08\% \leq \text{BAL} \leq 0.099\%$	930/22,500 =.0418 = V_8
Driver $\text{BAL} \geq 0.10\%$	3,878/22,500 =.1743 = V_{10}

Therefore:

(1a) $R_{10} \text{VMT}_{10} = .1743$; or $\text{VMT}_{10} = .1743/(16.04 \cdot R_0)$

(1b) $R_8 \text{VMT}_8 = .0418$; or $\text{VMT}_8 = .0418/(2.736 \cdot R_0)$

(1c) $R_1 \text{VMT}_1 = .0835$; or $\text{VMT}_1 = .0835/(1.147 \cdot R_0)$

(1d) $R_0 \text{VMT}_0 = .7004$; or $\text{VMT}_0 = .7004/R_0$

Recall that:

(1e) $\text{VMT}_{10} + \text{VMT}_8 + \text{VMT}_1 + \text{VMT}_0 = 1$

Substituting (1a) through (1d), we obtain

$$(.1743/(16.04 \cdot R_0)) + (.0418/(2.736 \cdot R_0)) + .0835/(1.147 \cdot R_0) + .7004/R_0 = 1$$

Solve for R_0 : $R_0 = .80$

Solve for VMT_{10} , VMT_8 , VMT_1 , and VMT_0 by inserting the value of R_0 into equations (1a) through (1d). The fractions are 0.014, 0.019, 0.091, and 0.876. Actual vehicle miles traveled at each blood alcohol level can be computed by multiplying total vehicle miles traveled by the fraction of total vehicle miles traveled at each BAL (VMT_{10} , VMT_8 , VMT_1 , and VMT_0).

Simpler variants of these equations also exist. For example, four equations may be written in four unknowns if we do not segment VMT driven with positive BAL below 0.10%. In this case, $R_{1-9.9} = 1.45 \cdot R_0$. Alternatively we could not segment VMT driven above 0.08% BAL. In this case $R_8 = 9.55 \cdot R_0$. Finally, we could simply estimate the fraction of miles driven above 0.10% BAL versus below 0.10% BAL including sober. In this case, $R_{10} = 15.78 \cdot R_{\text{base}}$, where R_{base} is the odds of a crash when driving below 0.10% BAL, 1.015. That implies $R_{\text{base}} = V_{10}/15.78 + V_{\text{base}}$, $\text{VMT}_{\text{base}} = V_{\text{base}}/R_{\text{base}}$, and $\text{VMT}_{10} = 1 - \text{VMT}_{\text{base}}$.

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